# MSE-Colloquium@NTU

**14 December 2016, 4.00 pm**
**Lecture Theatre 11, Nanyang Technological University**

**Understanding Stresses and Strains Across the Scales – Mechanical Microscopy Studies at the Oxford MBLEM lab**

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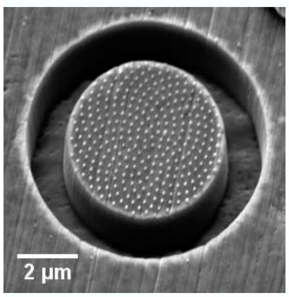
## About the Talk



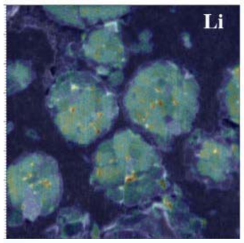

The Multi-Beam Laboratory for Engineering Microscopy (MBLEM) is part of a new micro-mechanical testing facility based in Oxford, UK which was setup by Professor Alexander Korsunsky in early 2014 (www.korsunsky.org). It combines the techniques of multi-modal microscopy, synchrotron radiation and neutron scattering to investigate a broad range of materials and mechanical systems.

The overarching purpose of the group's studies lies in elucidating the variety of ways in which materials and structures accommodate deformation and carry load at different scales and levels of organisation. To this end, mechanical microscopy is underpinned by multi-scale simulation using analytical and numerical methods and drawing on advanced finite element modelling, dislocation dynamics, molecular dynamics, etc. A few high profile examples of recent studies will be drawn upon, and are listed below.

**Microscale residual Stress analysis using the ring-core Focused Ion Beam (FIB) milling and Digital Image Correlation (DIC) approach [2-10].**

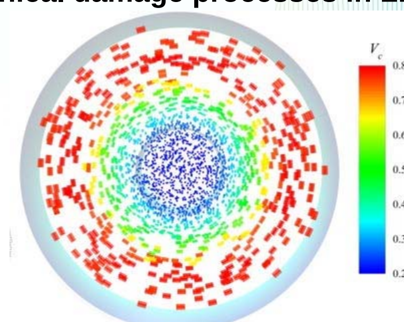
The ring-core FIB milling and DIC technique is based on introducing traction-free surfaces around a micron-scaled pillar of material on the surface of a substrate. Scanning Electron Microscopy (SEM) is used to record images of the pillar surface and DIC is used to quantify the strain relief as a function of milling depth. Comparisons of this behaviour with the relief curves predicted by Finite Element Analysis (FEA) are then used to back compute the residual stress originally present within the gauge volume. Our recent work has been focused on the error analysis associated with this technique [5-7] as well as at the extensions for intragranular [6, 8], depth-resolved [9] and laterally resolved micro-scale stress analysis [10].


**Understanding failure at Yttria Partially Stabilised Zirconia (YPSZ)-porcelain interface in dental prostheses [11-14].**




Porcelain near-interface chipping is induced by the complex residual stress state, microstructure and mechanical property variation induced within the first few hundred microns of the YPSZ-porcelain interface. In order to improve understanding of this behaviour, the near interface region has been analysed using experimental techniques including EDS, TEM and micropillar compression [11]. Bulk mechanical tests [12, 13] and new experimental techniques were developed to assess the single crystal stiffnesses of YPSZ from polycrystal neutron diffraction data [14].

**Understanding the cascade of electrochemical and mechanical damage processes in Li-ion battery cathodes [15-18].**




The increasing demand for portable, reliable and high energy storage systems has resulted in ever increasing use of Li-ion based battery systems. Widespread industry adoption of this technology is hampered by the lack of understanding of long-term degradation and capacity fading observed. Our recent studies have been directed towards the interaction between electromechanical and mechanical damage processes in these systems using a broad range of experimental techniques including FIB-SEM tomography [15], Raman and X-ray absorption spectroscopy [16] as well as FIB-SEM TOF-SIMS and correlative microscopy techniques [17]. This analysis has resulted in improved modelling of the internal stresses and damage in Li-ion battery cathodes [18].

**Micro-scale characterisation of deformation and fracture of advanced aerospace materials [10, 19-21].**

The increasingly stringent requirements to the thermo-mechanical properties of aerospace components in recent years has resulted in the development of a wide range of novel alloys, composite material systems and processing routes. Reliable understanding of the failure modes of these new systems is critical to facilitate widespread industrial use. This has served as the motivation for several our recent studies at MBLEM, including X-ray diffraction mapping of the residual stress state in carbon fibre reinforced titanium alloys [19] and EBSD analysis of fatigue crack propagation in Al alloy. The micro-scale ring-core FIB milling and DIC approach has also been widely applied to quantify residual stress variation in additive laser manufactured turbine blades [10], shot peened surfaces [20], and the impact of cyclic deformation in Ni-based single crystal superalloys [21].

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## About the Speaker

Professor Alexander Korsunsky is a world-leader in engineering microscopy of materials systems and structures for optimisation of design, durability and performance. He leads MBLEM lab at the University of Oxford, and the Centre for In situ Processing Science (CIPS) at Research Complex at Harwell. He consults Rolls-Royce plc on matters of residual stress and structural integrity, and is Editor-in-Chief of Materials & Design, a major Elsevier journal (2015 impact factor 3.501). Each year he chairs several major international conferences on engineering and materials, and gives several keynote and plenary lectures. He maintains extensive international collaborative links that included visiting appointments in Italy (Universitá Roma Tre), France (ENSICAEN), Hong Kong (HKPU) and Singapore (NUS, NTU, A*Star). Prof Korsunsky's research interests concern improved understanding of integrity and reliability of engineered and natural structures and systems, from high-performance metallic alloys to polycrystalline ceramics to natural hard tissue such as human dentin and seashell nacre. He co-authored books on fracture mechanics (Springer) and elasticity (CUP), and published ~350 papers in scholarly periodicals on subjects ranging from multi-modal microscopy, neutron and synchrotron X-ray analysis, contact mechanics and structural integrity to micro-cantilever bio-sensors, size effects and scaling transitions. His ISI h-index is 24, and his top paper was cited over 300 times. Prof Korsunsky plays a leading role in the development of large-scale research facilities in the UK and Europe. He chaired the Science Advisory Committee at Diamond Light Source, and is member of UK delegation to ESRF Council. His activities expand the range of applications of large-scale science to problems in real engineering practice.